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hill-sides; and again in the valleys, or gentle depressions between the rolling hills, are the rich purple tufts of *Astragalus bisulcatus* Gray. This is a very handsome perennial, and would be desirable enough for cultivation, but for its disgustingly strong odor of bean-vines.

Besides these more noticeable things, our ten miles walk added to our herbal several very interesting rarities, which would have been overlooked by one who had sought only the showy and beautiful things of this interesting ground. A remarkable profusion of very handsome flowers, of a few species only, is what especially characterizes the flora of this region at this season of the year. Passing through it by rail, one sees as much of the purple and red and white and yellow of the plants mentioned, as of the common verdure of the prairie grasses.

THE PRESENT ASPECTS OF BIOLOGY AND THE METHOD OF BIOLOGICAL STUDY.*

BY PROFESSOR ALLMAN.

Conception of Biology and Function of the Scientific Method.— Under the head of Biology are included all those departments of scientific research which have as their object the investigation of the living beings—the plants and the animals—which tenant the surface of our earth, or have tenanted it in past time.

It admits of being divided under two grand heads: Morphology, which treats of Form; and Physiology, which treats of Function; and besides these there are certain departments of biological study to which both Morphology and Physiology contribute, such as Classification, Distribution, and that department of research which is concerned with the origin and causes of living and extinct forms.

By the aid of observation and experiment we obtain the elements which are to be combined and developed into a science of living beings, and it is the function of the scientific method to indicate the mode in which the combinations are to be effected, and the path which the development must pursue. Without it the results gained would be but a confused assemblage of isolated facts and disconnected phenomena; but, aided by a philosophic method, the observed facts become scientific propositions; what was apparently insignificant becomes full of meaning, and we get glimpses of the consummate laws which govern the whole.

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* Extracts from the opening address before Section D—Biology—of the British Association for the Advancement of Science, delivered Sept. 18, 1873.

Classification an Expression of Affinities.—Hitherto we have been considering the individual organism without any direct reference to others. But the requirements of the biological method can be satisfied only by a comparison of the various organisms one with the other. Now the grounds of such comparison may be various, but what we are at present concerned with will be found in anatomical structure and in developmental changes; and in each of these directions facts of the highest order and of great significance become apparent.

By a carefully regulated comparison of one organism with another, we discover the resemblances as well as the differences between them. If these resemblances be strong, and occur in important points of structure or development, we assert that there is an affinity between the compared organisms, and we assume that the closeness of the affinity varies directly with the closeness of the resemblance.

It is on the determination of these affinities that all philosophic classification of animals and plants must be based. A philosophical classification of organized beings aims at being a succinct statement of the affinities between the objects so classified, these affinities being at the same time so set forth as to have their various degrees of closeness and remoteness indicated in the classification.

Affinities have long been recognized as the grounds of a natural biological classification, but it is only quite lately that a new significance has been given to them by the assumption that they may indicate something more than simple agreement with a common plan—that they may be derived by inheritance from a common ancestral form, and that they therefore afford evidence of a true blood relationship between the organisms presenting them.

The recognition of this relationship is the basis of what is known as the Descent Theory. No one doubts that the resemblances we notice among the members of such small groups as those we name species are derived by inheritance from a common ancestor, and the Descent Theory is simply the extension to the larger groups of this same idea of relationship.

If this be a true principle, then biological classification becomes an exposition of family relationship—a genealogical tree in which the stem and branches indicate various degrees of relationship and direct and collateral lines of descent. It is this conception which takes classification out of the domain of the purely morphological.

Affinity determined by the study of Anatomy and Development.—From what has just been said it follows that it is mainly by a comparison of organisms in their anatomical and developmental characters that their affinities are discoverable. The structure of an organism will in by far the greater number of cases be sufficient to indicate its true affinity, but it sometimes happens that certain members of a group depart in their structure so widely from the characters of the type to which they belong, that without some other evidence of their affinities no one would think of assigning them to it. This evidence is afforded by development.

A Philosophical Classification cannot form a single Rectilineal Series.—A comparison of animals with one another having thus resulted in establishing their affinities, we may arrange them into groups, some more nearly, others more remotely related to one another. The various degrees and directions of affinity will be expressed in every philosophical arrangement, and as these affinities extend in various directions, it becomes at once apparent that no arrangement of the animal or vegetable kingdom, in a straight line ascending like the steps of a ladder from lower to higher forms, can give a true idea of the relations of living beings to one another. These relations, on the contrary, can be expressed only by a ramified and complex figure which we have already compared to that of a genealogical tree.

Distribution and Evolution.—Another very important department of biological science is that of the distribution of organized beings. This may be either distribution in space, geographical distribution: or distribution in time, palæontological distribution. Both of these have of late years acquired increased significance, for we have begun to get more distinct glimpses of the laws by which they are controlled, of the origin of faunas and floras, and of the causes which regulate the sequence of life upon the earth. Time, however, will not allow me to enter upon this subject as fully as its interest and importance would deserve, and a few words on palæontological distribution are all that I can now venture on.

The distribution of organized beings in time has lately come before us in a new light by the application to it of the hypothesis of evolution. According to this hypothesis, the higher groups of organized beings now existing on the earth's surface have come down to us, with gradually increasing complexity of structure, by continuous descent from forms of extreme simplicity which constituted the earliest life of our planet.

In almost every group of the animal kingdom the members which compose it admit of being arranged in a continuous series passing down from more specialized, or higher, to more generalized or lower forms; and if we have any record of extinct members of the group, the series may be carried on through these. Now while the descent hypothesis obliges us to regard the various terms of the series as descended from one another, the most generalized forms will be found among the extinct ones, and the farther back in time we go the simpler do the forms become.

By a comparison of the forms so arranged we obtain, as it were, the law of the series, and can thus form a conception of the missing terms and continue the series backwards through time, even where no record of the lost forms can be found, until from simpler to still simpler terms we at last arrive at the conception of a term so generalized that we may regard it as the primordial stock, the ancestral form from which all the others have been derived by descent.

This root form is thus not actually observed, but is rather obtained by a process of deduction, and is therefore hypothetical. We shall strengthen, however, its claims to acceptance by the application of another principle. The study of embryology shows that the higher animals, in the course of their development, pass through transitory phases which have much in common with the permanent condition of lower members of the type to which they belong, and therefore with its extinct representatives. We are thus enabled to lay down the further principle that the individual, in the course of its own development from the egg to the fully formed state, recapitulates within that short period of time the various forms which its ancestry presented in consecutive epochs of the world's history; so that if we knew all the stages of its individual development, we should have a long line of its descent.

Through the hypothesis of evolution, palæontology and embryology are thus brought into mutual bearing on one another.

Let us take an example in which these two principles seem to be illustrated. In rocks of the Silurian age there exist in great profusion the remarkable fossils known as graptolites. These consist of a series of little cups or cells arranged along the sides of a common tube, and the whole fossil presents so close a resemblance to one of the Sertularian hydroids, which inhabit the waters of our present seas, as to justify the suspicion that the graptolites constitute an ancient and long since extinct group of the Hydroida. It is not, however, with the proper cells or hydrothecæ of the Sertularians that the cells of the graptolite most closely agree, but rather with the little receptacles which in certain Sertularinæ belonging to the family of the Plumularida we find associated with the hydrothecæ, and which are known as "Nematophores." A comparison of structure then shows that the graptolites may with considerable probability be regarded as representing a Plumularia in which the hydrothecæ had never been developed and in which their place had been taken by the nematophores.

Now it can be shown that the nematophores of the living Plumularida are filled with masses of protoplasm which have the power of throwing out pseudopodia, or long processes of their substance, and that they thus resemble the Rhizopoda, whose soft parts consist entirely of a similar protoplasm and which stand among the Protozoa, or lowest group of the animal kingdom. If we suppose the hydrotheca suppressed in a plumularian, we should thus nearly convert it into a colony of Rhizopoda, from which it would differ only in the somewhat higher morphological differentiation of its cænosarc or common living bond, by which the individuals of the colony are organically connected. And, under this view, just such a colony would a graptolite be, waiting only for the development of hydrotheca to raise it into the condition of a plumularian.

Bringing now the evolution hypothesis to bear upon the question, it would follow that the graptolite may be viewed as an ancestral form of the Sertularian hydroids, a form having the most intimate relations with the Rhizopoda; that hydranths and hydrothecæ became developed in its descendants; and that the rhizopodal graptolite became thus converted, in the lapse of ages, into the hydroidal Sertularian.

This hypothesis would be strengthened if we found it agreeing with the phenomena of individual development. Now such Plumularida as have been followed in their development from the egg to the adult state do actually present well-developed nematophores before they show a trace of hydrothecæ, thus passing in the course of their embryological development through the condition of a graptolite, and recapitulating within a few days stages which it took incalculable ages to bring about in the palæontological development of the tribe.

I have thus dwelt at some length on the doctrine of evolution because it has given a new direction to biological study and must powerfully influence all future researches. Evolution is the highest expression of the fundamental principles established by Mr. Darwin, and depends on the two admitted faculties of living beings—*heredity*, or the transmission of characters from the parent to the offspring; and *adaptivity*, or the capacity of having these characters more or less modified in the offspring by external agencies, or it may be by spontaneous tendency to variation.

The hypothesis of evolution may not, it is true, be yet established on so sure a basis as to command instantaneous acceptance; and for a generalization of such vast significance no one can be blamed for demanding for it a broad and indisputable foundation of facts. Whether, however, we do or do not accept it as firmly established, it is at all events certain that it embraces a greater number of phenomena and suggests a more satisfactory explanation of them than any other hypothesis which has yet been proposed.

With all our admiration, however, for the doctrine of evolution as one of the most fertile and comprehensive of philosophic hypotheses, we cannot shut our eyes to the difficulties which lie in the way of accepting it to the full extent which has been sometimes claimed for it. It must be borne in mind that though among some of the higher vertebrata we can trace back for some distance in geological time a continuous series of forms which may safely be regarded as derived from one another by gradual modification—as has been done, for example, so successfully by Prof. Huxley in the case of the horse—yet the instances are very few in which such a sequence has been actually established; while the first appearance in the earth's crust of the various classes presents itself in forms which by no means belong to the lowest or most generalized of their living representatives. On this last fact, however, I do not lay much stress, for it will admit of explanation by referring it to the deficiency of the geological record, and then demanding a lapse of time—of enormous length, it is true—during which the necessary modifications would be in progress before the earliest phase of which we have any knowledge could have been reached.

Again, we must not lose sight of the hypothetical nature of those primordial forms in which we regard the branches of our genealogical tree as taking their origin; and while the doctrine of the recapitulation of ancestral forms has much probability, and harmonizes with the other aspects of the evolution doctrine into a beautifully symmetrical system, it is one for which a sufficient number of actually observed facts has not yet been adduced to remove it altogether from the region of hypothesis.

Even the case of the graptolites already adduced is an illustration rather than a proof, for the difficulty of determining the true nature of such obscure fossils is so great that we may be altogether mistaken in our views of their structure and affinities.

To me, however, one of the chief difficulties in the way of the doctrine of evolution, when carried out to the extreme length for which some of its advocates contend, appears to be the unbroken continuity of inherited life which it necessarily requires through a period of time whose vastness is such that the mind of man is utterly incapable of comprehending it. Vast periods, it is true, are necessary in order to render the phenomena of evolution possible; but the vastness, which the antiquity of life, as shown by its remains in the oldest fossiliferous strata, requires us to give to these periods, may be even greater than is compatible with continuity.

We have no reason to suppose that the reproductive faculty in organized beings is endowed with unlimited power of extension, and yet to go no farther back than the Silurian period—though the seas which bore the Eozoon were probably as far anterior to those of the Silurian as these are anterior to our own—the hypothesis of evolution requires that in that same Silurian period the ancestors of the present living forms must have existed, and that their life had continued by inheritance through all the ramifications of a single genealogical tree down to our own time; the branches of the tree, it is true, here and there falling away, with the extinction of whole genera and families and tribes, but still some always remaining to carry on the life of the base through a period of time to all intents and purposes infinite. It is true that in a few cases a continuous series of forms regularly passing from lower to higher degrees of specialization, and very probably connected to another by direct descent, may be followed through long geological periods, as, for example, the graduated series already alluded to, which may be traced between certain mammals of the Eocene and others living in our own time, as well as the very low forms which have come down to us apparently unmodified from the epoch of the Chalk. But incalculably great as are these periods, they are but as the swing of the pendulum in the millennium, when compared to the time which has elapsed since the first animalization of our globe.

Is the faculty of reproduction so wonderfully tenacious as all this, that through periods of inconceivable duration, and exposed to influences the most intense and the most varied, it has still come down to us in an unbroken stream? Have the strongest which had survived in the struggle for existence necessarily handed down to the strongest which should follow them the power of continuing as a perpetual heirloom the life which they had themselves inherited? Or have there been many total extinctions and many renewals of life—a succession of genealogical trees, the earlier ones becoming old and decayed, and dying out, and their place taken by new ones which have no kinship with the others? Or, finally, is the doctrine of evolution only a working hypothesis which, like an algebraic fiction, may yet be of inestimable value as an instrument of research? For as the higher calculus becomes to the physical inquirer a power by which he unfolds the laws of the inorganic world, so may the hypothesis of evolution, though only a hypothesis, furnish the biologist with a key to the order and hidden forces of the world of life. And what Leibnitz and Newton and Hamilton have been to the physicist, is it not that which Darwin has been to the biologist?

But even accepting as a great truth the doctrine of evolution, let us not attribute to it more than it can justly claim. No valid evidence has yet been adduced to lead us to believe that inorganic matter has become transformed into living, otherwise than through the agency of a preëxisting organism, and there remains a residual phenomenon still entirely unaccounted for. No physical hypothesis founded on any indisputable fact has yet explained the origin of the primordial protoplasm, and, above all, of its marvellous properties which render evolution possible.

Accepting, then, the doctrine of evolution in all freedom and in all its legitimate consequences, there remains, I say, a great residuum unexplained by physical theories. Natural Selection, the Struggle for Existence, the Survival of the Fittest, will explain much, but they will not explain all. They may offer a beautiful and convincing theory of the present order and fitness of the organic universe, as the laws of attraction do of the inorganic, but the properties with which the primordial protoplasm is endowed—its heredity and its adaptivity—remain unexplained by them, for these properties are their cause and not their effect.

For the cause of this cause we have sought in vain among the physical forces which surround us, until we are at last compelled to rest upon an independent volition, a far-seeing intelligent design. Science may yet discover even among the laws of physics the cause it looks for; it may be that even now we have glimpses of it; that those forces among which recent physical research has demonstrated so grand a unity—light, heat, electricity, magnetism—when manifesting themselves through the organizing protoplasm, become converted into the phenomena of life, and that the poet has unconsciously enunciated a great scientific truth when he tells us of

> " Gay lizards glittering on the walls
> Of ruined shrines, busy and bright
> As though they were *alive with light.*"

But all this is only carrying us one step back in the grand generalization. All science is but the intercalation of causes, each more comprehensive than that which it endeavors to explain, between the great primal cause and the ultimate effect.

I have thus endeavored to sketch for you in a few broad outlines the leading aspects of biological science, and to indicate the directions which biological studies must take. Our science is one of grand and solemn import, for it embraces man himself and is the exponent of the laws which he must obey. Its subject is vast, for it is life, and life stretches back into the illimitable past, and forward into the illimitable future. Life, too, is everywhere. Over all this wide earth of ours, from the equator to the poles, there is scarcely a spot which has not its animal or its vegetable denizens—dwellers on the mountain and on the plain, in the lake and on the prairie, in the arid desert and the swampy fen; from the tropical forest with its strange forms and gorgeous colors and myriad voices, to the ice-fields of polar latitudes and those silent seas which lie beneath them, where living things unknown to warmer climes congregate in unimaginable multitudes. There is life all over the solid earth; there is life throughout the vast ocean, from its surface down to its great depths, deeper still than the lead of sounding line has reached.

And it is with these living hosts, unbounded in their variety, infinite in their numbers, that the student of biology must make himself acquainted. It is no light task which lies before him — no mere pastime on which he may enter with trivial purpose, as though it were but the amusement of an hour; it is a great and solemn mission to which he must devote himself with earnest mind and with loving heart, remembering the noble words of Bacon: —

"Knowledge is not a couch whereon to rest a searching and restless spirit; nor a terrace for a wandering and variable mind to walk up and down with a fair prospect; nor a tower of state for a proud mind to raise itself upon; nor a fort or commanding-ground for strife and contention; nor a shop for profit and sale; but a rich storehouse for the glory of the Creator, and the relief of man's estate."

REVIEWS AND BOOK NOTICES.

THR SYSTEMATIC POSITION OF THE BRACHIOPODS.* — To those accustomed to find the Brachiopods invariably mentioned in palæontological as well as zoological works as shell-fish, with no hint of an affinity to any other class of animals, the author's remark at the beginning of his essay that "the Brachiopoda are true worms, with possibly some affinities to the Crustacea, and that they have no relations to the Mollusca, save what many other worms may possess in common with them," will seem in its nature somewhat iconoclastic. But we should remember that Cuvier regarded the barnacles as Mollusca, and it was not until 1830 that Thompson and Burmeister demonstrated from their mode of growth that these shell-bearing animals were undoubted Crustacea; the Serpulæ and Spirorbes were regarded as shell-fish by many collectors, and even

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*The Systematic Position of the Brachiopoda. By Edward S. Morse. (From the Proceedings of the Boston Society of Natural History, xv. Published August, 1873. 8vo. pp. 60.)